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Comments on FAA 14 CFR Part 25 "Revised Landing Gear Shock Absorption Test Requirements and Proposed Advisory Circular 25.723-1, Shock Absorption Test: Proposed Rule and Notice"

FAA-97-5835-7

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Comments to: Docket No. FAA – 1999 – 5835, Notice No. 99 – 08.

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INTRODUCTION

The following comments and suggestions apply to the proposed rule changes that were presented in the above document. These comments are not confined to the purpose for which the revisions were originally proposed (namely to "impact" the environment, energy or economy, as explained in the paragraph titled "Comments Invited"). They are written with a broader attitude in mind, because unless these rules and changes are expressed in a clear and logical manner, they will be badly understood, regardless of their aim. The design rules in the FAA 14 CFR Part 25 Airworthiness Standards: Transport Category Airplanes, also constitute the legal assurances for flight safety, and it is necessary that their introduction is not only unambiguous, but also is easy to comprehend.

Unlike certain other subjects within the Airworthiness Regulations that have been treated in a less definitive manner (such as the Fatigue Evaluation in §25.571), the Ground Loads have always been prescribed in considerable detail for specified load cases and the means of finding their numerical values has been well defined. Although this approach results in a degree of conservatism in landing gear design, there is no implied nor formally stated intention to relax this policy and the following remarks are made with this attitude in mind.

The writer has been working in the analysis of ground loads of landing gears on civil aircraft for almost 30 years. He is well aware of the many problems of structural design and analysis of landing gears, and of the connection between these difficulties and the various complications that arise from the use of the particular landing gear airworthiness regulations within FAR 25.

DISCUSSION OF CHANGES

In the proposed revisions, 525.473 will have an additional sub-Section (d), and the two Sections §25.725 and §25.727 will be removed. §25.723 will be rewritten with the intention making it effective without the two Sections that previously followed.

The addition §25.473 (d) will call for the validation of the computerized simulations, which are to be the basic method of finding the dynamic loads. This validation will be achieved by performing a limited number of drop-tests to obtain certain outputs, but for which many of the other requirements will be omitted. In particular the maximum vertical loads are not required to be found directly. The current method for the design of landing gears does not specify a refined logical simulation process (using a digital computer) for finding the landing impact loads. Since many of these load cases can be calculated by hand, it is possible for the results to be conservative (or even to be too small). As proposed, more precise loads are obtainable when using the computer, and presumably some significant structural weight can be saved once this

refined method is generally adopted. Therefore the proposal will employ the drop-tests, only for purposes of validating these simulations, whilst the F.A.A. will accept that the current kinds of computer programs (that in practice are often employed by the manufacturers) are reasonable, and satisfy §25.471 (a) (2) after validation.

This approach without 525.725 and 525.727 also will replace the use of "landing impact load factor", that was found from the drop-test results, with the actual external loads and forces (as determined from the computerized analysis).

COMMENT #1. §25.473

Concerning the logic within the Sections, the current version takes as it's applicable "landing conditions" the Sections in §25.479 through 525.485, namely "level landing conditions", "tail-down landing conditions", "one-gear landing conditions" and "side load conditions". After the changes are introduced, these four landing conditions will be tied to the drop-test by §25.473 (d). However the actual purpose of the drop testing will be aimed only at confirming the results of the computerized analysis, so that not all of these four conditions (particularly the last two non-symmetric ones) can or need to be checked by the specified drop testing. Hence it would be more logical for the additional sub-paragraph (d) to state that it is for the two symmetrical landing conditions called by §25.473, that validation by test now applies. It is suggested that this alteration to the wording should be made.

Presumably here the asymmetric landing cases ("conditions") will not need to be simulated by computer, in order to satisfy the proposed changes to the requirements. However if these kinds of simulation are also intended for inclusion in the proposal, then certain additional improvements will be needed in the Regulations. These changes concern the definition of the main landing gear lateral geometry, the tire side friction effects and the use of the rolling inertia of the aircraft, for the determination of the associated forces and motion.

COMMENT #2. §25.473 (d)

The connection with the four design cases or "landing conditions", that will be made by the addition of 525.473 (d), somewhat vaguely calls for validation of the "dynamic characteristics". This term might simply refer to the damping coefficient of the hydraulic orifice, or to a pair of values from the shock absorber's load/compression curve, and not to the total energy capacity nor to any other alternate overall property of the shock absorber. Thus it is not clear which performance parameters will be confirmed by proceeding with the drop-test. This change in the requirements will result in them being left open to different interpretations, depending on the regulation authorities and/or designers/analysts who are involved. Definition of the various kinds of dynamic characteristics is necessary (if not, then all of the specific requisite qualities themselves should be included). It is suggested here that these properties of the landing gears should be specified in a more precise manner.

COMMENT #3. §25.723 (a)

The omission of the drop-test requirements in Sections 525.725 and §25.727 will have two separate effects on the flow of logic within the analysis. Firstly, presumably as intended, there will now be no need to present the method for the correction of the

"effective mass", that is used as the carriage mass in drop testing without lift forces. All that will be (apparently) needed from the test is that the energy absorbed must be shown to be correct. It is not clear in §25.723 if this applies at limit or ultimate (Reserve-Energy) conditions. But it is clear that the necessary conditions for performing the drop-tests now will be less restricting than the conditions specified in 525.479 through §25.481, because the proposed regulation is inconsistent with these Sections. In particular there is an important difference between "range of landing conditions, airplane configurations, and service variations expected in operation" and the four kinds of landings specified in these former Sections, particularly for the significant symmetric level and tail-down landings (as noted above in Comment #1).

The omission of the Reserve Energy condition means that this drop-test is no longer mandatory. This change will result in a reduction in the degree of safetv that is to be demonstrated. It is suggested that the paragraph be modified to include the critical drop-tests, which are needed to physically prove a sufficiency in the reserves of energy absorption capacity, within the shock absorber design. (It is not suggested that the dynamic strength of the landing gears be demonstrated here, although it should be remembered that certain materials exhibit greater dynamic strength than static strength. Consequently such a demonstration in lieu of static testing, has use in enabling the design to be executed at reduced structural weight, provided that the dynamics of the associated horizontal loads are correctly included.)

In a similar manner to the first paragraph of this comment, the change calls for the conformity to be "in a manner consistent with the development of rational or conservative limit loads". As an example, this approach certainly could now allow for the influence of both ground-effect and flight-path angle to reduce the assumed value of tail-down pitch-angle relative to the ground. If there is indeed an intention to ease the design problems here, no explanation has yet been provided for the use of these more moderate proposed landing conditions. Incidentally, these do not comply with the previous 525.473, nor provide for the same (exaggerated) level of safety as that obtained by the existing conservative regulations.

COMMENT #4. §25.725 and 925.727 in *absentia.*

The second effect of the omission is that the method for calculation of equivalent mass at the nose landing gear will now be eliminated. This is satisfactory, only in so far as the previous method depended on the height of the center of gravity amongst other input quantities - an approach that is not physically correct. However there always exists an equivalent mass on the nose gear, even without any horizontal deceleration being present, see Ref 2. It is most significant, and it has use in determining the energy for absorption and the loads developed on the nose gear.

The subject of equivalent mass at the nose has never been examined in depth. Preliminary studies have shown that the effect of the equivalent mass raises the vertical forces on the nose gear by approximately 2.5 times, see Refs. 1 and 2 (although Ref.3 shows that this is not always true). Hence at this time it is not advisable to determine the value of equivalent mass, solely by simulation of the forces and aircraft motion (in heave and pitch with gear compressions). Although this approach is useful, it is suggested that in addition to these simulations (to find the vertical loads on the nose gear), a requirement should be introduced to measure the equivalent mass and sinking-speed there. Alternatively these quantities could be found by similarity with other aircraft. After a tail-down landing, the pitching effect on the nose gear sinking-speed (at the instant of it's touch down), usually results in the occurrence of a smaller value than previously felt at the main gear. These quantities

can be easily obtained by the measurement of the regular landing impacts at the nose gear, during the early stages of the flight test program (as in the example recently performed in Ref.3).

The results will provide some practical knowledge of the nose gear landing conditions and equivalent mass, which enable the design loads to be found by computation and simulation and for the dynamics to be better understood. The greatest demands for energy absorption by this gear are not necessarily generated during level landings, and the full range of pitch angle should be examined by simulation, starting with the main gear impact. The equivalent mass when multiplied by half the square of the vertical speed at the instant of nose gear impact, provides the vertical kinetic energy. This energy equals the amount that is to be absorbed by this gear, according to the subsequent load/displacement history part of the simulation.

With the small additional expense of the testing (which is not difficult to include in the regular flight testing procedures of prototypes), the improvement and greater accuracy of the design conditions for nose gears loads is of benefit for the design of these gears and their supporting structures.

In the proposals, no division of the cost saving for the nose-gear part of the program was mentioned. With the introduction of the above test, the reduction in cost will be slightly smaller than if the new regulations were completely adopted, but here it is of greater importance and significance to use more realistic design conditions and to accurately determine the resulting ground loads at the nose gear.

CONCLUSIONS

1. Four comments have been made concerning the proposed changes to the above referenced Airworthiness Regulations.

2. Incorporation of the suggestions (that are associated with these comments) into the proposed revisions, would considerably improve the clarity and context of these changes in a useful manner.

REFERENCES:

1. “Landing Gear Loads of Civil Transport Airplanes” 0. Buxbaum,
8 th. Plantema Lecture of the 11 th. I.C.A.F. Symposium 20-05-81.

2. “The Equivalent Masses at Nose landing-Gears During Landing-Impacts and When Taxiing Over Runway Perturbations” D.H. Chester,
Proceedings of the 27 th. Annual Conference on Aviation and Astronautics, Israel Journal of Technology Vol. 23 1986/87.

3. “Development of a Fatigue-Spectrum for the Nose Landing-gear on the Galaxy Executive Jet” D.H. Chester and A. Brot,
Proceedings of the 26 th. Symposium of I.C.A.F. Bellevue, Washington. July 1999. (To be published).